USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Watershed Based Optimization Approach for Identification and Management of Non-Point Source Pollution

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Focus Categories: WQL, M & P, LIP

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Critical Regional or State Water Problems: Area of Relevant Research

Agricultural NPS pollution was identified as the major threat to the Nation's water quality in the 1992 Clean Water Act Amendment. Many efforts have been initialized to reduce the agricultural NPS pollution; however, EPA still reported NPS as the primary source for impaired streams and lakes. The Michigan Department of Environmental Quality (MDEQ) identified hundreds of watersheds that had NPS pollution problems in early 1998. These watersheds will need a "watershed performance based plan" not only to address NPS pollution problems but also to implement solutions that will optimally reduce the NPS pollution. The research will address both environmental and economic issues in NPS pollution management.

Results or benefits

With EPA's emphasis on watershed and total maximum daily loading (TMDL), watershed planners critically need a systematic economic/environmental watershed NPS pollution optimization approach. The selected study area is the Stony Creek watershed, which is one of the NPS problem (303d) watersheds identified by the MDEQ. The watershed covers 115,000 acres of land and approximately 85% of the watershed is agriculture. The final research result is a user friendly performance based NPS watershed management system for the Stony Creek watershed. This NPS watershed management planning tool can serve as the guidance or strategy for the watershed communities to meet both environmental and economic goals in the NPS pollution management. However, several intermittent outcomes can also be expected. First, the methodology itself will demonstrate a solid scientific-based approach for NPS pollution management. Secondly, the investigation of the cost-effectiveness of alternative Best Management Practices (BMP's) can generate knowledge to help facilitate scenario analysis for NPS pollution management assessment. Finally, the watershed experience can be applied to other watersheds that have NPS pollution problems. We have developed and applied several components for the NPS pollution management and planning tool, including web-based Revised Universal Soil Loss Equation (RUSLE) and buffer strip design using Geographic Information System (GIS).

Nature, scope, and objectives of the research:

Nature/Scope: This proposed project investigates Non-Point Source (NPS) pollution management from a watershed perspectives. The research addresses both environmental and economic issues in NPS pollution management. The goal is to provide scientific, informed decision-making for NPS pollution management. The results will be applicable to other watersheds that have NPS pollution problems. With EPA's emphasis on watershed and total maximum daily loading (TMDL), watershed planners critically need a systematic economic/environmental watershed NPS optimization approach for selection from a set of farm level locations and options.

The selected study area is the Stony Creek watershed, which is one of the NPS problem (303d) watersheds identified by the MDEQ. The watershed covers 115,000 acres of land and approximately 85% of the watershed is agriculture. It has been estimated that the point sources contributed approximately one-third of the phosphorus loading and the rest are mainly from NPS's including agriculture. The watershed stakeholders are currently working together to meet the environmental goal set by the MDEQ while maintaining the economic viability of all stakeholders.

Objectives**:** The overall objective is to use the Stony Creek River Watershed as a case study for the evaluation of performance-based management approach to restore and protect water quality.

Specifically, the sub-objectives are to:

1. *Use mechanistic watershed hydrologic models and farm-level models to:*

   a. characterize reaches (and their sub-watersheds) throughout the Stony Creek River watershed (urban, sub-urban, and rural) with the highest risk of water quality impairment from phosphorus;

   b. determine specific land areas with high potential for contributing NPS pollution to reaches in the high-risk sub-watersheds;

2. *Evaluate the general validity and effectiveness of watershed models for predicting reaches at high risk from phosphorus loadings through physical and biological monitoring of reaches;*

3. *Assess a farmer's set of proposed BMPs and evaluate their relative cost-effectiveness in reducing potential phosphorus loading to the reach;*

4. *Develop and coordinate coalitions of stakeholders into appropriate focus groups needed to evaluate their willingness to accept, adopt, and maintain recommendations and procedures stemming from this study.*

Methods, procedures, and facilities:

***Overview of Strategies*:** NPS pollution has a diffuse, dynamic, and stochastic nature. In order to address these characteristics, a three-step management procedure will be used. The first step is critical area identification. A watershed-based simulation model is used to investigate what the pollutants are and where the pollution occurs. This step integrates both historical monitoring data and gross modeling to characterize the identity of pollutants in the aquatic system. The second step focuses on the terrestrial system, i.e., sub-watersheds, that contributed most to the NPS pollution problem. Then, the third step uses a mass-balance farm-level approach to assess phosphorus loading and farm level options. Together, utilizing the three steps above, an area-wide set of management options can be generated. The research team is working closely with the watershed communities to facilitate understanding of the potentials of this approach.

Approach:

1) *Use mechanistic watershed hydrologic and farm-level models to:*

   a) *characterize reaches (and their sub-watersheds) throughout the Stony Creek River watershed (urban, sub-urban, and rural) with highest risk of water quality impairment from phosphorus;*

This approach - uses a basin scale model with generalized input data. The goal is to better understand the loadings and their sources throughout the watershed. This overview will assist the watershed stakeholders to obtain a more accurate and spatially correct "view" of the loading throughout the watershed. Further, a general ranking of "potential" degree of impairments by reaches (sub-watersheds) throughout the watershed will be obtained. Preliminary analysis has been conducted to assess the NPS loading potential in the watershed based on geographic characteristics such as slopes.

The focus is to evaluate existing general phosphorus loading distribution on the watershed. The Better Assessment Science Integrating Point and Non-point Sources (BASINS v.2) developed by EPA is used as the primary tool. BASINS contains three models integrated in a GIS environment. The Non-Point Source Model (NPSM) estimates land-use-specific non-point source loading for a watershed through the Hydrologic Simulation Program – FORTRAN (HSPF). A one-dimensional, steady-state water quality and eutrophication model (QUAL2E) allows fate and transport modeling for both point and non-point sources. The TOXIROUT model, a screen-level stream routing model, performs simple dilution/decay calculations under mean or low flow conditions for a stream system within a watershed. In addition, a set of assessment tools (TARGET, ACCESS, and Data Mining) also exist in BASINS to facilitate model data input and model output evaluation.

At the basin scale management, only generalized natural resource data will be used for analysis. These data include coarse resolution land use, topography, and statewide soil maps, long-term average weather information, as well as point source (phosphorus loading) from the National Pollution Discharge Elimination System (NPDES). The study watershed will be divided into sub-watersheds. The analysis will focus on the Total Maximum Daily Load of Phosphorus (TMDLP) of each sub-watershed.

With the three analytical models in BASINS, two types of results can be derived. First, the non-point source contribution from the terrestrial system (land) of a sub-watershed can be compared and ranked. Secondly, by combining indirect non-point source input from the land with direct point source discharge to the water, each stream reach (aquatic system) can be compared and ranked. These two ranking systems will provide a base understanding of the spatial distribution of TMDLP in both terrestrial and aquatic systems of the study watershed. The sub-watersheds will then be ranked using several types of values derived from BASINS for their relative contribution to the phosphorus degradation that impair the water system.

b) determine specific land areas with high potential for contributing NPS pollution to the reaches in high-risk sub-watersheds;

The second step of watershed level analysis will focus on the sub-watershed scale. The goal is to identify specific areas within the most impaired sub-watershed that have the greatest potential for contributing to the degradation of water quality. By calculating loading to cells (segments) of the river, the model results will help provide important information for maximizing the restoration of the aquatic system.

Each sub-watershed will be examined with different hypothetical scenarios. The purpose at this tier is to examine the landscape response of potential alternatives. It is important to understand the ecological carrying capacity within a sub-watershed and the sensitivity of the landscape responses to possible changes of management.

Agricultural Non-Point Source (AGNPS v.5) model developed by USDA ARS at Morris, MN along with GIS will be the major analytical tool at this sub-watershed level analysis. AGNPS is a distributed physical process simulation model for evaluating agricultural non-point source pollution on a watershed basis. However, AGNPS also accepts point source input. It contains four basic modules, namely: hydrology, soil erosion and sedimentation, nutrient (phosphorus and nitrogen), and pesticide. AGNPS requires division of a watershed into small grids and each grid requires a set of input parameters. Two types of outputs are available in AGNPS. Watershed outlet output contains summaries of hydrological, nutrient, sediment, and pesticide information. Detailed results of each module are also available for each grid within the watershed. The AGNPS model emphasizes on relative comparison of different farm level management practices within a watershed context. Preliminary study has been conducted on AGNPS modeling and its GIS interface.

For the purposes of this proposed research, the hydrologic, phosphorus, and sediment components are of interest. The sub-watershed level of management analysis will need detailed data. These data include field boundaries, crop rotation, farming management practices, channel profile, finer contour, and county soil. A set of alternative farming management will be identified first. These management practices will be "converted" into adjustable control variables in the AGNPS model. The research will use a multi-criteria optimization approach to evaluate results of alternative scenarios. By defining TMDLP at specific stream reaches as the goal in the optimization framework, a set of initial alternative management practices for different farms in the sub-watershed can be randomly generated. Then, a min-max optimization approach will be applied to "search" for better results that met all goals of reduced runoff and phosphorus loadings.

The final outcome is a set of solutions. Each solution will have a set of landscape setting, that is, "where to apply what". By examining the landscape setting of each set of solutions, generalized rules for each sub-watershed can be derived. These rules represent how the landscape responds to changes of management practices. In addition, the TMDLP goals also imply the ecological carrying capacity that can be achieved for the targeted sub-watershed. These generalized rules by sub-watershed provide guidance to further refine farm level management.

2) *Evaluate the general validity and effectiveness of integrated watershed models for predicting reaches at high risk from phosphorus loadings through physical and biological monitoring of reaches.*

Physical and biological monitoring in reaches of sub-watersheds is being conducted during 1999 and 2000. The goal is to develop enough data to generally rank the waters of the sub-watershed by their impairments with emphasis on phosphorus levels. This ranking will be compared with the BASINS v.2 modeling outputs. Also, selected sampling will occur just up and down stream from a set of calculated high risk areas. Four to six sub-watersheds will be continuously monitored. All of the reaches in the 12 sub-watersheds of the Stony Creek Watershed will be sampled for biological indicators, and generally correlated with phosphorus loadings.

The physical monitoring will be conducted by the USGS as part of their expanding responsibility associated with 303d impaired reaches and allowable total maximum daily load (TMDL) level development. The Fisheries Division of the MDNR supervises the biological sampling. They have developed scientifically reviewed methods for using biological indicators for indexes of impairment of water quality particularly those characteristics associated with phosphorus-induced eutrophication.

This water quality evaluation will help in assessing and interpreting the overall results of the BASINS v.2 model and directly help the watershed community understand the watershed impairments.

3) *Assess a farmer's set of proposed BMPs and evaluate their relative cost-effectiveness in reducing potential phosphorus loading to the reach.*

The farm level model will generate predicted P loading increases (or reductions) to farm fields and associated costs. This field loading data will then become part of the input to the AGNPS model that will calculate loadings to the water with present and then proposed practices. Thus, changes in loadings to the water course (reach) can be estimated.

By setting hypothetical TMDL values for the reach, alternative farm-level management practices can be identified. Each set of options can be evaluated with both economic (cost) and environmental effectiveness (TMDL at the reach) goals. The system allows for further simulations of proposed plans or scenarios within each stakeholder group in the watershed.

> 4) Develop and coordinate coalitions of stakeholders into appropriate focus groups needed to evaluate their willingness to accept, adopt, and maintain recommendations and procedures stemming from this study.

We are working with the Stony Creek Watershed Committee, the local communities including schools, and the local farmers to develop coalitions of stakeholders groups representing each that will be used to identify and understand local priorities and problems related to surface water and nonpoint pollution patterns found in the watershed. These same groups will be used help set research priorities and to evaluate various management alternatives and procedures.

Acceptance and adoption of BMP, policies, and educational programs will be evaluated within each stakeholder group to evaluate the impact of this project.

Related research

A relatively long history of federal support from numerous agencies has provided the background for modeling and data acquisition that can be used in this project. In the late 1980's, the Engineering Division of the Soil Conservation Service, USDA provided support for work on linking geographic information systems (GIS) to spatial hydrologic/watershed models (Vieux et al., 1987 and 1990). That support to programs, such as GRASS Waterworks, and numerous other publications. Many of those concepts were subsequently integrated into the Hydrologic Unit Water Quality (HUWQ) modeling effort of NRCS, USDA that has been distributed nationally. The US Geological Survey (USGS) provided a grant which supported work on the integration of GIS and a computer model to evaluate impacts of agricultural runoff on water quality (Kang et al., 1992). This project used the AGNPS (Agricultural Non-Point Source pollution model for Evaluating Agricultural Watersheds) for designating land areas with high potential nonpoint source contribution to water (Young et al., 1989 and He et al., 1993).

(Joe Ervin from our staff has over two decades of water quality sampling experience through NRCS/EPA, 319, and MDEQ.)

Joint support for the EPA Region 5 and USDA was received to develop a Wetlands Information Management System (WIMS) for facilitating wetland evaluation. In this system several evaluation approaches were integrated and automated through computer programming and linkages to GIS. Further, a user-friendly graphical interface was developed specifically for this application. That work subsequently has been funded to develop 1) a decision support system at the township level and 2) a statewide wetland tracking and information system for the Michigan Department of Environmental Quality. This system incorporates characteristics of wetlands, permits granted, and related research information.

Support from the Corps of Engineers has been obtained over the last several years for a preliminary decision support and analysis system for watershed-based wetland trading. This project has developed a total system with GIS, wetland characteristics, and optimization all integrated into a user-friendly package for applications related to environmental or watershed planning and wetland trading (Brumbaugh, et al., 1994).

Training potential

The majority of the budget is for graduate assistantships with at least two graduate students supported from this grant. Also, several other graduate students will assist with the research and utilize the information generated. At least one undergraduate student will assist with data preparation**.**

Information transfer plan:

1. *Define the subject matter and problems to be addressed:* Watershed planners throughout the United States are confronted with the challenge of reducing water quality impairments particularly from NPS within specified reaches for which they have responsibility. Few tools presently exist to aid with where to put BMPs to maximize benefits to water quality. The results of this proposal will be an integrated evaluation system for assessing and prioritizing areas and management practices which will have an optimal positive benefits on water quality.

2. *Identify the target audience:* Audiences involve those associated with watershed planning and management, and agency personnel responsible for providing funding to assist with implementing practices throughout the watershed for the improvement of water quality. Also, local elected officials, local leaders, and citizens can each impact water quality decisions. Specifically, water quality committees or organizations that are being formed to address impaired reaches throughout the United States will be a priority audience. These watershed organizations will be the most important target for transferring the findings from this research.

3. Indicate the strategies to be employed; e.g. workshops, publications: We are cooperating with local units of government that are supported by the MDEQ, Farm Bureau, Extension Service, and numerous industries. Each of these organizations will facilitate the transfer process from within their organization. Education programs within Extension Service will be part of the technology transfer approach through the development of information and training, through workshops, a Web site, and a list of personnel contacts who have been associated with the project. A brochure will be developed to enhance the general awareness of this activity. Further, a number of list server such as Great Lakes Information Network (GLIN) and those associated with the organizations cooperating on the project, will be used as additional resources for heads up awareness for the findings of this effort.

Identify the cooperators (e.g. Cooperative Extension Service): Both of the principle investigators are partially paid by the Extension Service thus they have established linkages to this outreach organization. Further, we have contacts throughout the eight state Midwest region associated with NRCS and the land grant universities.

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